

A Smarter Grid — Harmonized AC and DC Grids

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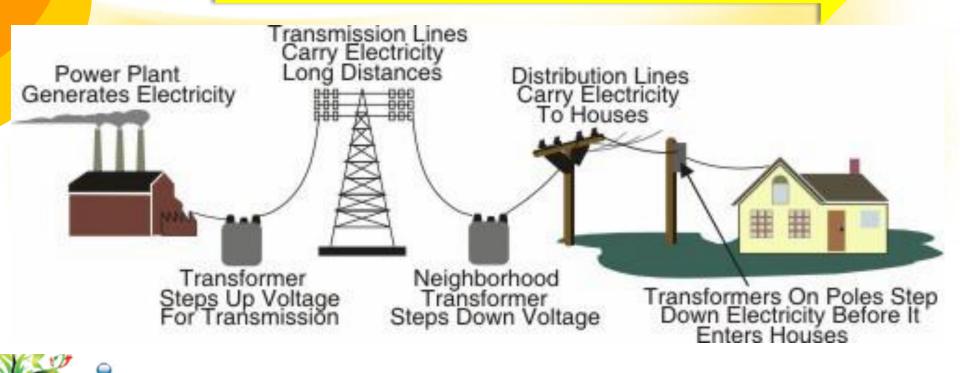
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Outline

- Smart Grid
- Development of Smart Grid
- W Harmonized AC and DC Grids A Smarter Grid
- Wey Components and Potential Market Size
- **Opportunities**
- Challenges
- **Concluding Remark**

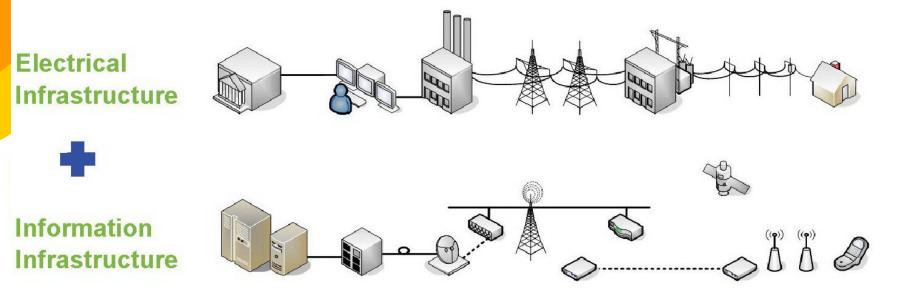
Traditional Grid

One-way power flow, simple interactions



Sources: ABB

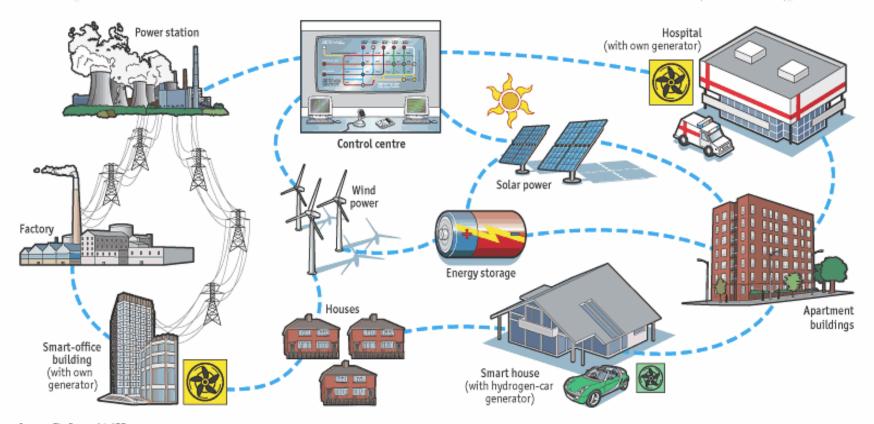
The integration of two infrastructures



Sources:: (1) UtilityPoint, by Ethan Cohen 7/18/0 (2) EPRI® Intelligrid

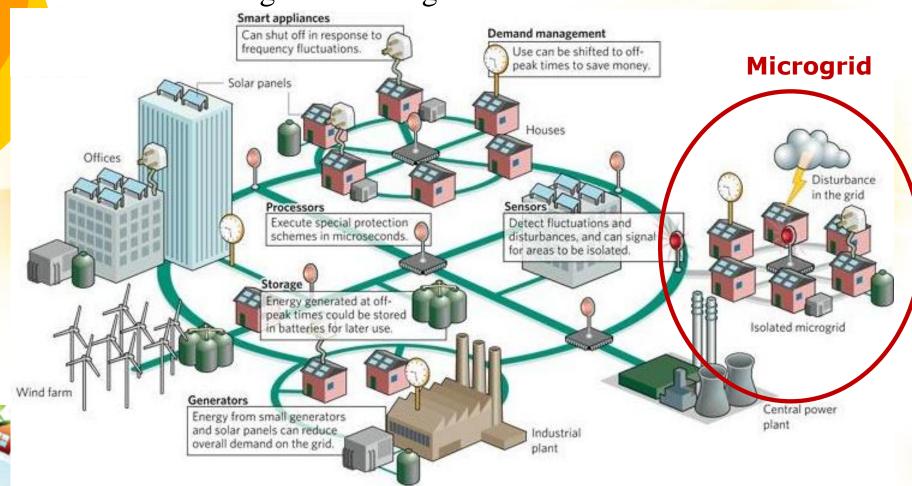


Multi-way power flow, information flow and multi-stakeholder interactions



Sources: The Economist; ABB

- A vision for the future
- A network of integrated microgrids that can monitor and heal itself.



Smart Grid Benefits

Increasing grid efficiency

Energy consumed to generate electricity

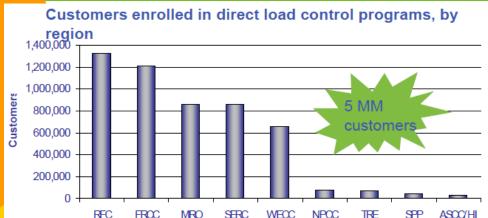


Smart Grid delivers:

- ✓ Utility savings: \$46MM/yr (2% total load reduction)
- ✓ Environmental benefits: 290K tons of CO2 reduction

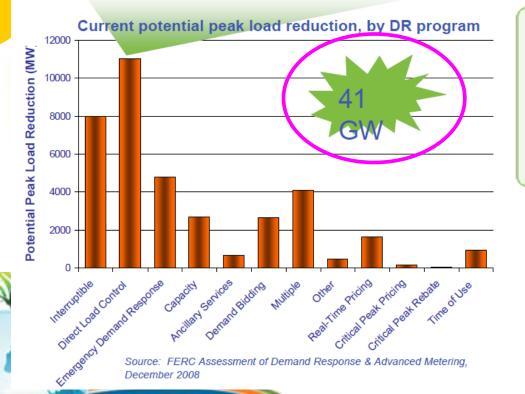


Reducing peak load demand



"Demand response is clearly the 'killer application' for the smart grid."

- Jon Wellinghoff, FERC Commissioner, Dec. 29, 2008

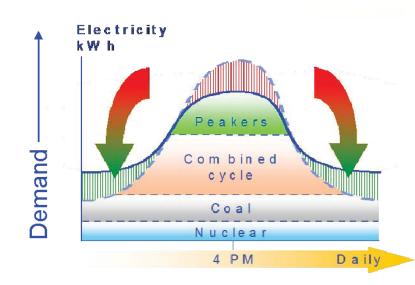


- ✓ Current DR programs can reduce peak load demand by up to 41 GW (~6% of peak demand for 2008).
- ✓ Utilities reported 13.6 GW of *actual* peak load reduction in 2007.
- √ Smart grid-enabled DR programs may achieve peak load reductions of 7%-22%¹

¹Electric Advisory Committee, "Keeping the Lights On in a New World," January 2009

Optimizing Demand - Creating Value to Consumer





Pacific Northwest National Laboratory announces the results of two studies demonstrating consumers and information technology can play an active role in managing the grid

"On average, consumers who participated in the project saved approximately 10 percent on their electricity bills"

Save 10 % of electricity bills



Development of Smart Grid

- Advanced Metering
 Infrastructure (AMI)(storing
 how electricity was used at
 different times of the day)
- Smart meter adds communications, so that monitoring can be done in real time
- Smart meter acts as a gateway to demand response-aware devices

1990S

➤ Italy's Telegestore Project (completed in 2005) networks 27 million homes with smart meters via low bandwidth power line communication

2000S

> Automatic meter reading

19805



- > Boulder, Colorrado completed the first phase of its smart grid project, using the smart meter as a gateway to the Home **Automation Network (HAN).**
- ➤ Austin, Texas, <u>supporting 500,000 smart devices real-time</u>.





> Ontario smart grid system served 1.3 million customers.



2009 ~ 2012: South Korea constructs a test-bed and works on the Smart Power Grid, Smart Places and Smart Transportation, linking grid network to consumers and EVs.



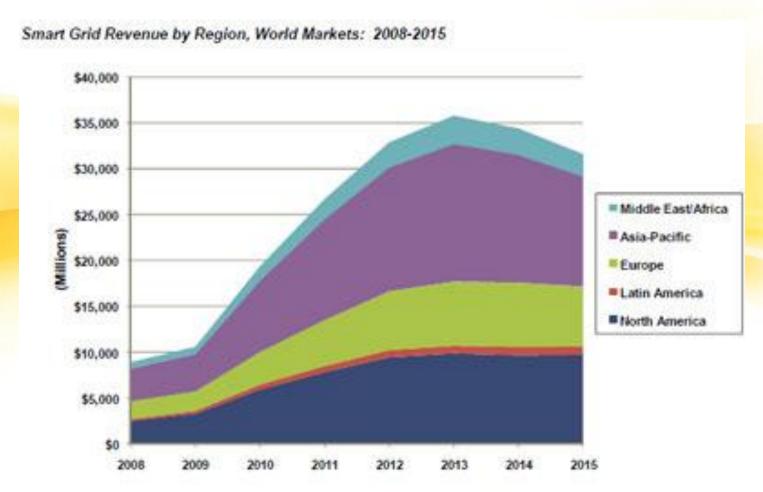
2013 \sim 2020; taking the best outcomes from the test-**Phase II** bed and commercializing them.





2021 ~ 2030: Completing the national smart grid.

Smart grid market to reach \$200 billion by 2015



Smart Meter Market

2015: > 71 million units, annual growth

rate of 25.3 %



2011: 1 million units

2020: 63 million units



2011: \$128.9 billion





- **♦** Improve Efficiency
- **♦** Increase Reliability
- **♦ Improve Power Quality**
- **♦ Increase Flexibility**
- **♦ Reduce Electricity Price**
- **♦ Shift Peak Load**







W Harmonized AC and DC Grids —

A Smarter Grid

- Share of Green Energy by 2030
- **Germany >50%**
- Denmark >50%
- **Japan >30%**
- **China** >25% (15 % by 2020)
- Taiwan>25%
- USA >20%



Spain >20% (by 2020)



Italy > 17% (by 2020)



UK >15% (by 2020)



Thailand > 13% (by 2022)



Korea > 11%



Malaysia >10% (by 2020)



Indonesia >10% (by 2025)

Renewable Energy

- PV, Wind, Wave, Tide, etc.
 - Intrinsically unstable and discontinuous
 - No constant frequencyand no constantamplitude

Note:

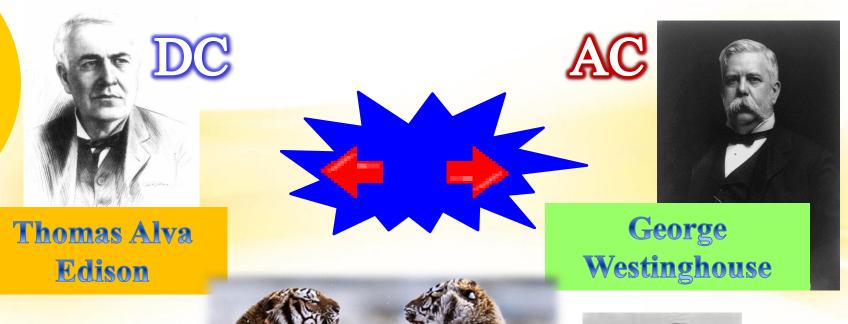
30 % of wind turbines in China are not connected to a transmission network.



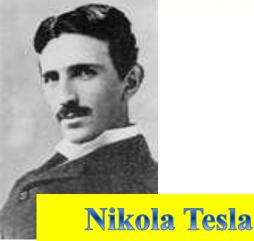


Harmonized AC and DC Grids

War of Currents: 1886~1895







Harmony

Balanced and gentle "give and take" situation Mutual benefit, win-win feature



"Harmony" in the family is the basis for success in any undertaking

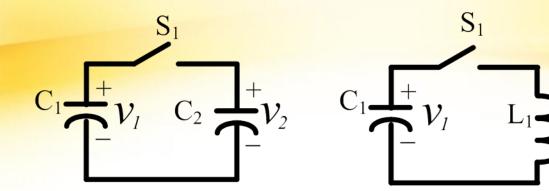
(家和萬事興)





Resonance

- > Smooth power delivery and reception
- Most efficient power transfer



without resonance

with resonance



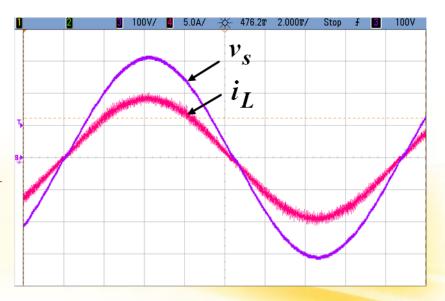
Resonance

- Applications
 - Motor drive
 - Battery charging
 - Blood circulation (based on Qi theory)
- **♦ Require well tuned frequency and amplitude**



AC Source

- Sinusoidal voltage waveform
- Expected sinusoidal current waveform



AC Grid



Existing AC Grid

- 50Hz / 60Hz
- 90~265 Vac (universal line voltage)

- **♦** Cannot fit to all kinds of load applications with resonance
- **♦** Require a transition state



DC Grid

- Reset un-tuned frequency and amplitude to dc state
- Act as a buffer and transition to new resonance

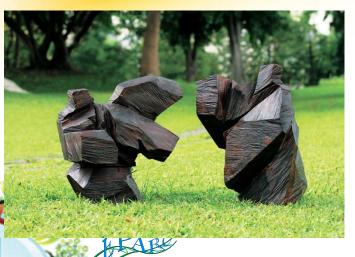


Harmonized AC and DC Grids

■ AC Grid (Source)

- Providing a strong backup
- Achieving high efficiency and smooth operation



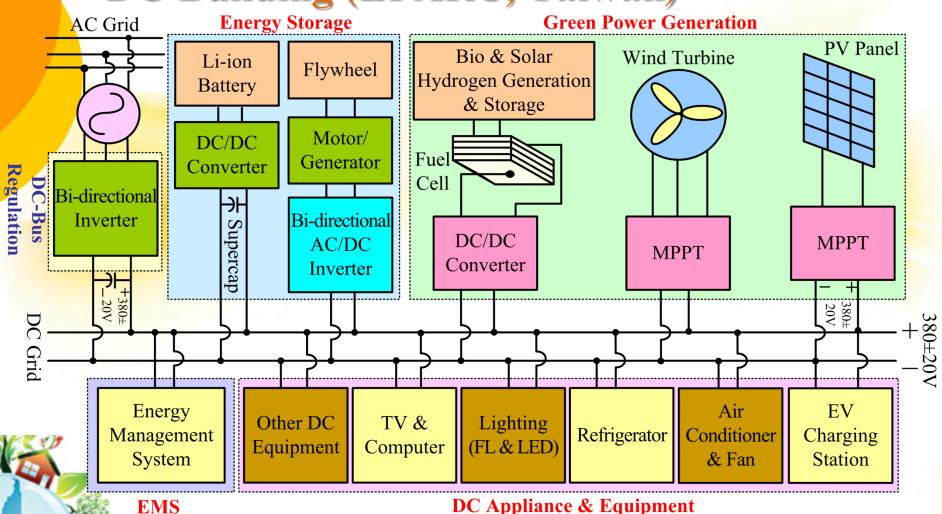


DC Grid (Source)

 Providing a buffer and transition to new resonance

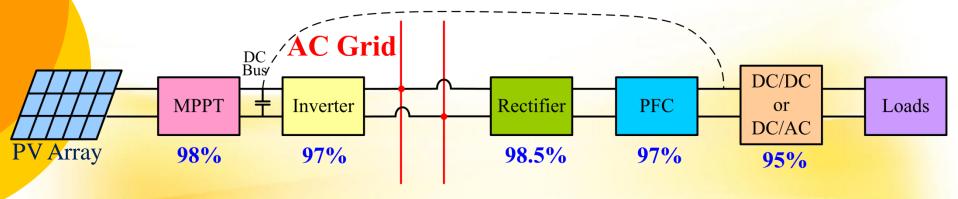
System Configuration

DC Building (EPARC, Taiwan)

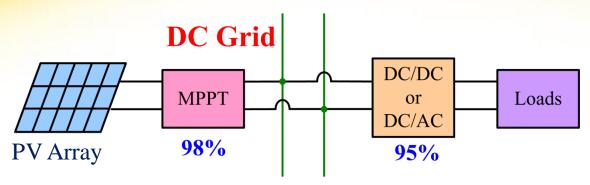


Unique Features

Energy saving: 8%



$$\eta_1 = 98\% \times 97\% \times 98\% \times 97\% \approx 85\%$$

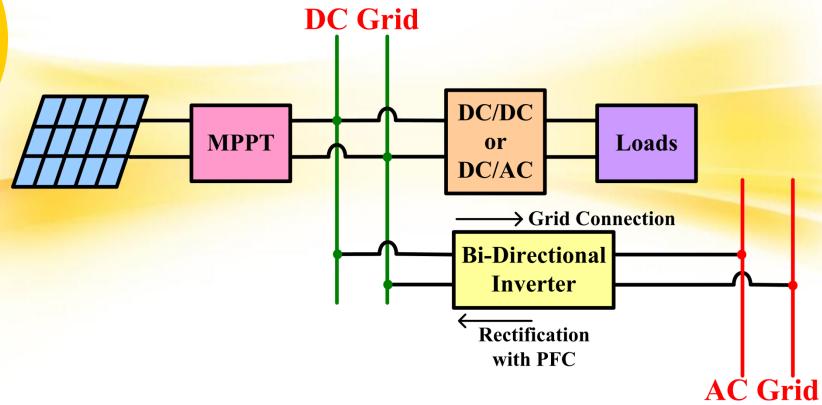


$$\eta_2 = 98\% \times 95\% \approx 93\%$$

$$\eta_2 - \eta_1 = 8\%$$
 (Less Power Loss)

Cost Reduction: 25%

■ In practice, it requires a bi-directional inverter to regulate DC-Grid voltage.





Improving AC-Grid Quality and Stability

- no harmonics
- less interference with AC grid
- with energy storage elements to buffer unstable green energy
- with energy management system to optimize energy usage and cost effectiveness

Easy to expand power capacity

- no frequency and no phase issues
- no circulation current



 Easy to accommodate various types of green distributed generators

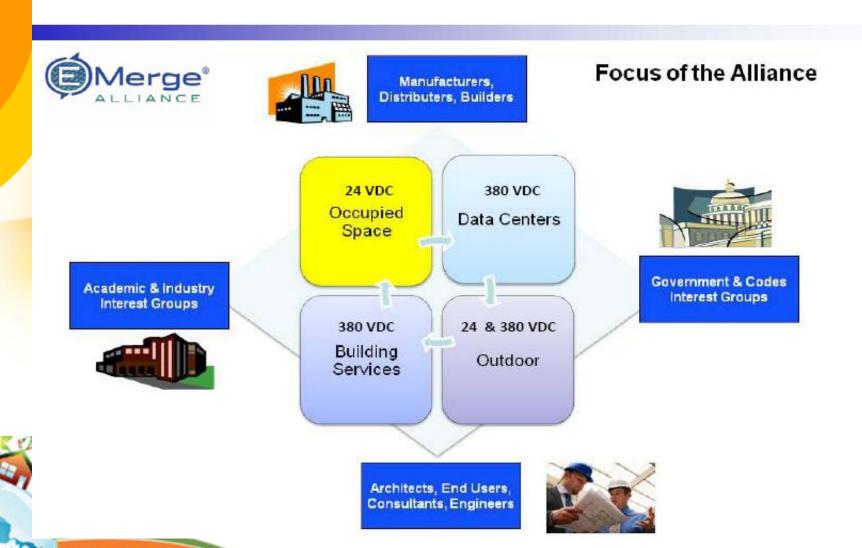
- PV Panel + MPPT -> DC Grid
- Wind turbine + MPPT → DC Grid
- Fuel Cells + DC/DC → DC Grid
- Piezoelectric Devices + DC/DC → DC Grid



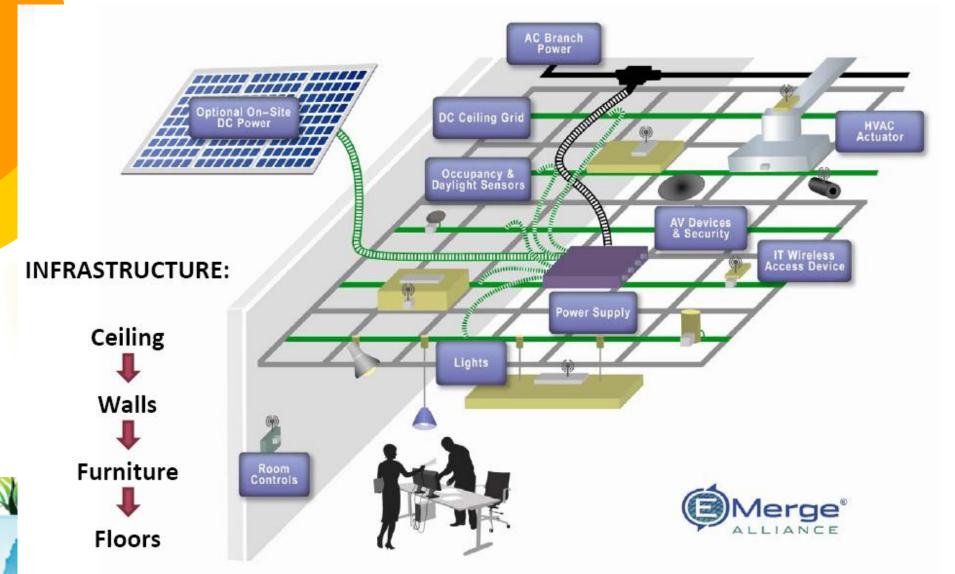
Easy to implement multiple functions

- **DC UPS**
- Charging/ Discharging
- PFC
- Grid Connection
- APF

Developing System DC Microgrids Throughout Buildings



DC 24V- Infrastructure



Luniera Lighting - DC 24V LED Luminaries

- 2200E Series 2 x 2
 - Ultra-thin
 - LED fixture
 - Direct replacement for 2
 X 4 foot flourescents

Luniera Lighting – 24V LED Luminaries

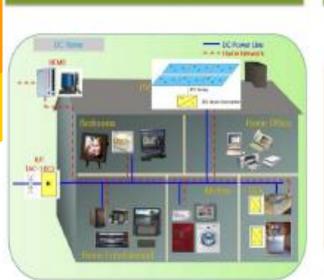




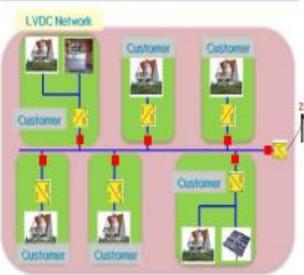
Korea – LVDC: 380 V, MVDC: 22.9 kV

Korean roadmap of DC distribution system

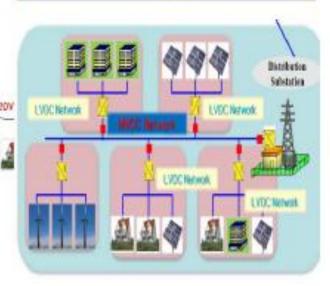
Step 1 (2011~2013) SMART DC



Step 2 (2014~2020) LVDC



Step 3 (2021~2030) MVDC

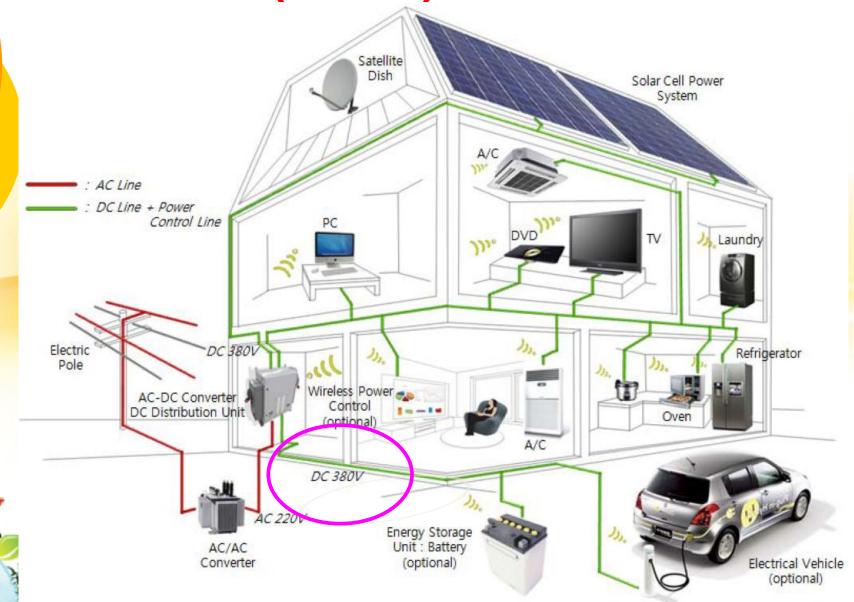


- End user DC distribution
 system 380 V
 - House, Small building level
- LVDC commercialization
 - 22.9kV/380V Tr.
 - Collective house area, office building

- MVDC commercialization
 - 22.9kV Feeder
 - City



Green Home (Korea) — DC 380 V



CPES (USA) - DC 380 V

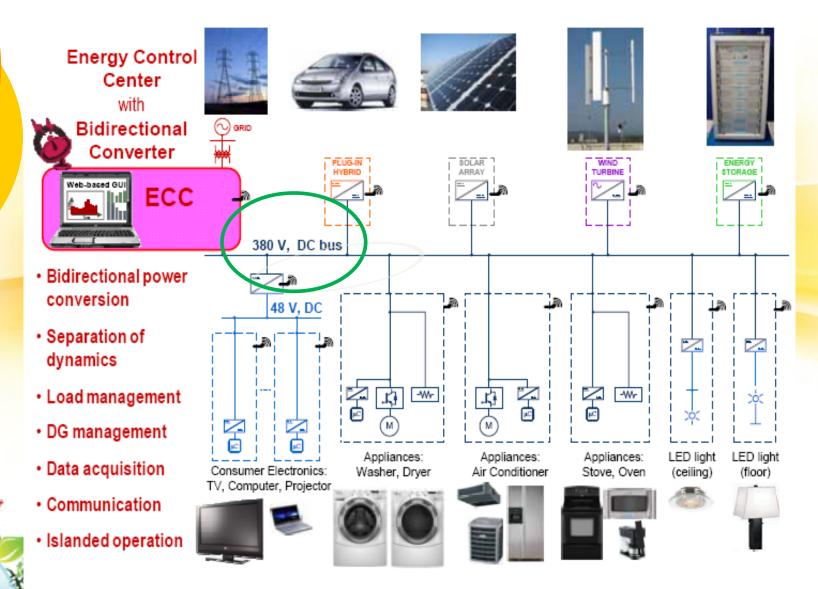
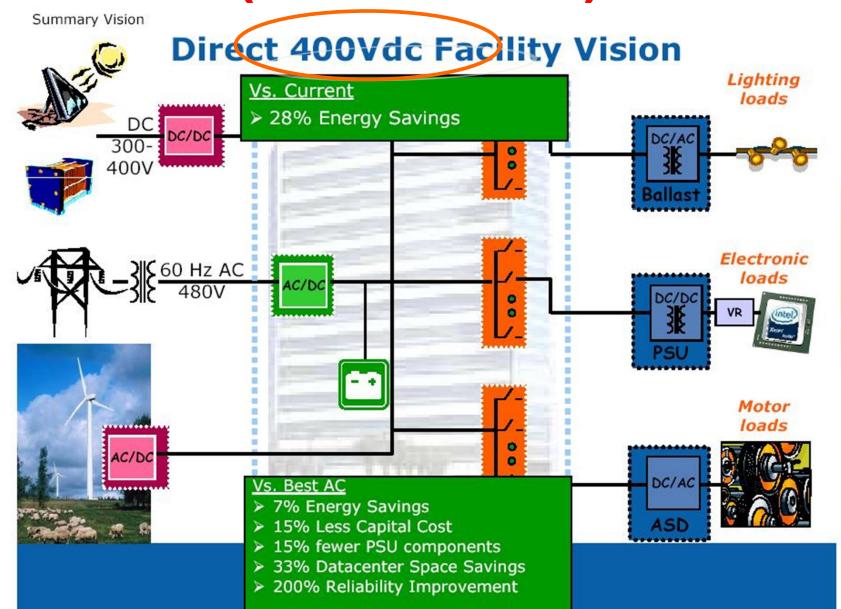
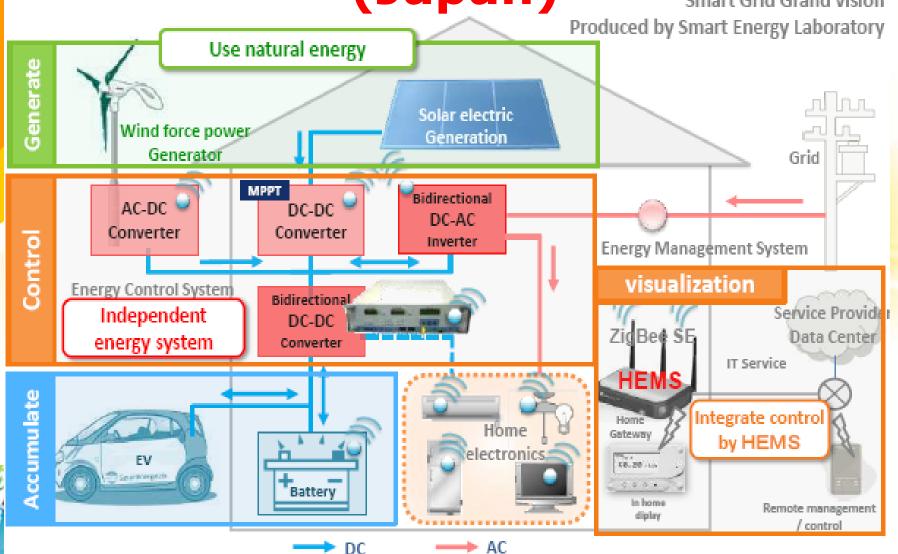


Fig. 5: Conceptual dc nanogrid in a future home.

Intel (Data Center)



Fukuoka Smart House – DC 380 V (Japan) Smart Grid Grand vision



DC self consumption as part of German renewable energy act

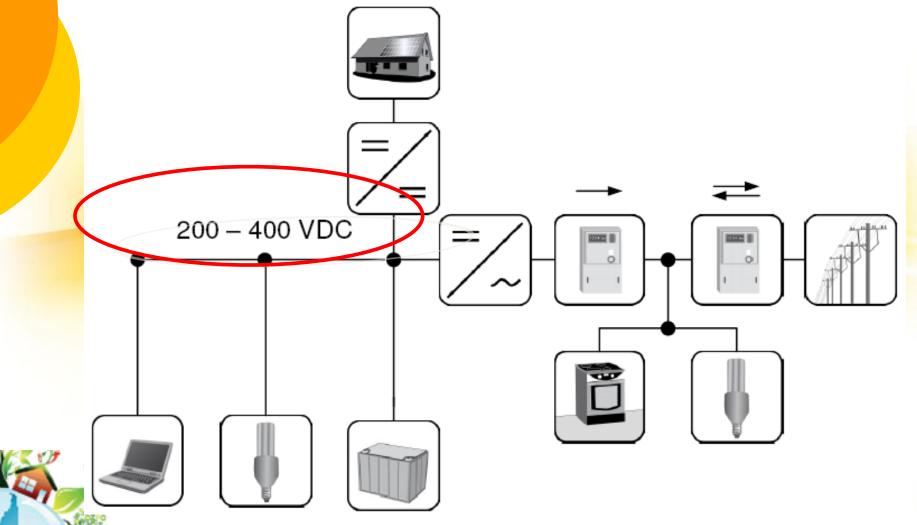
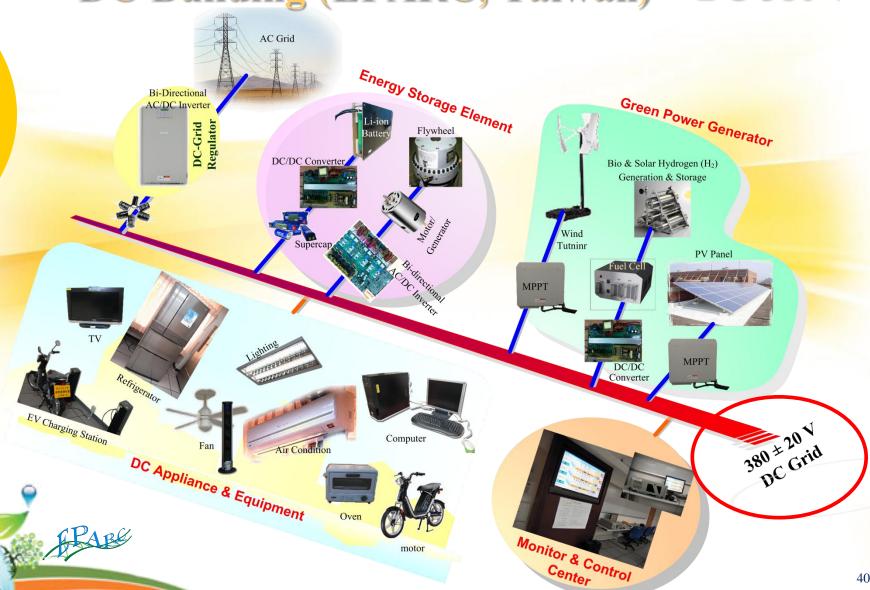
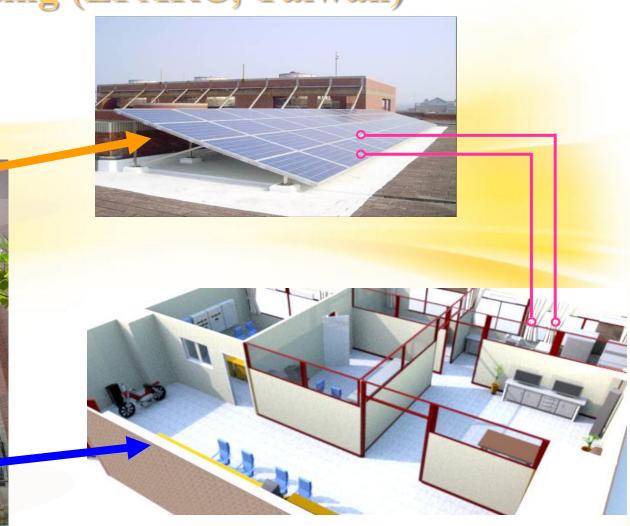


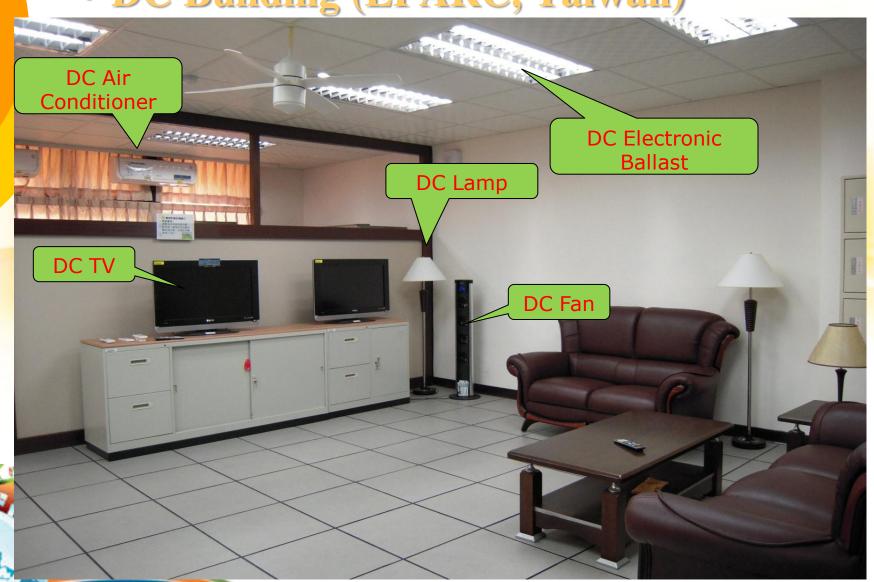
Image: Fraunhofer ISE, Freiburg, Germany

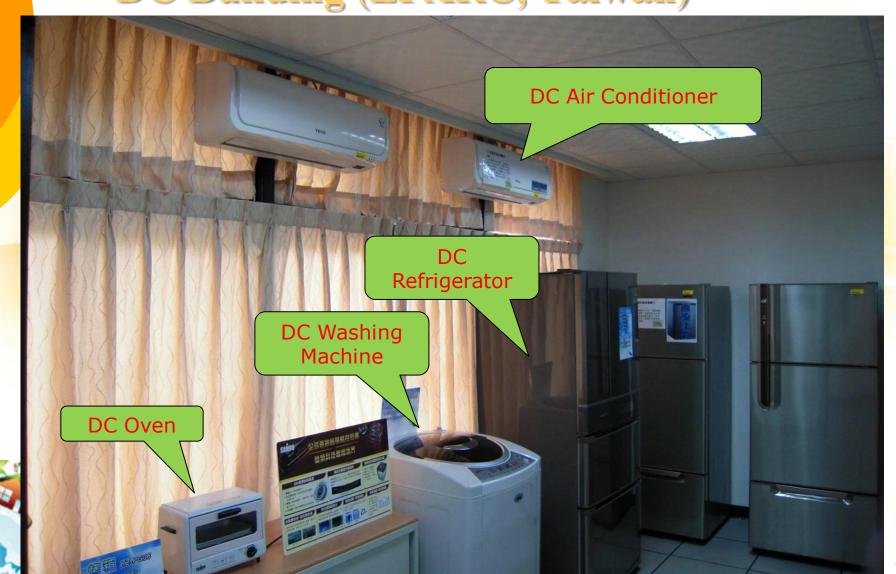
• DC Building (EPARC, Taiwan) – DC 380 V







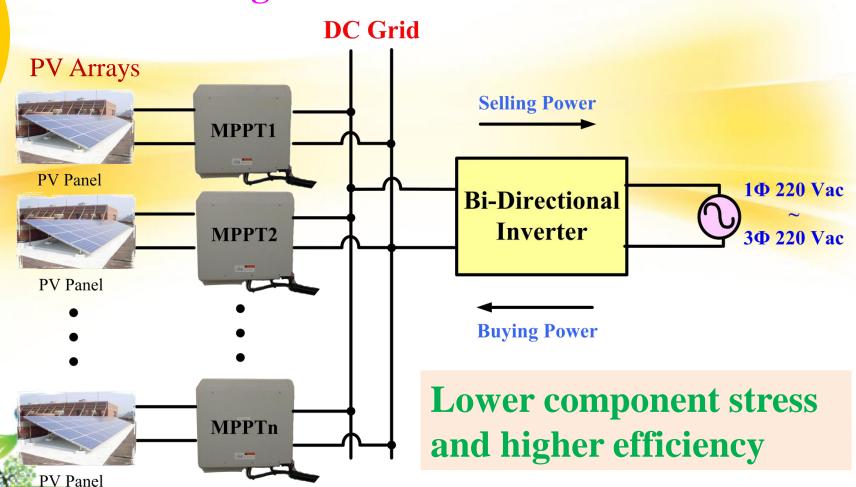




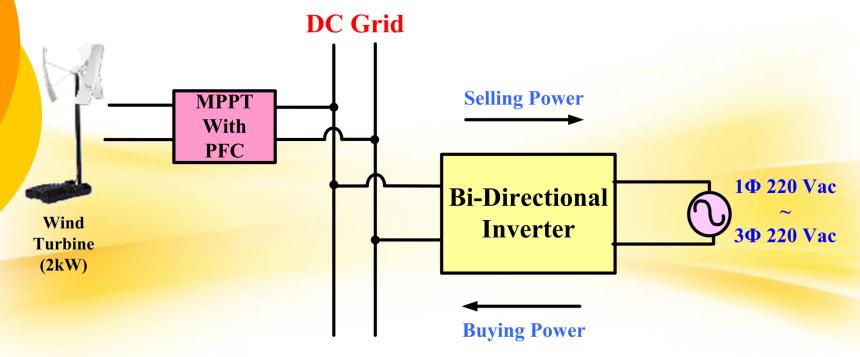
Key Components

Green Distributed Generators

Multi-String MPPT+ Grid-Tied Inverter

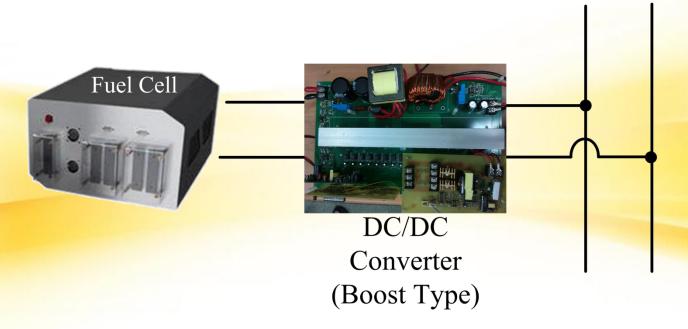


Wind Turbine + MPPT



- Wind Turbine Voltage: 0~200V
- DC-Grid Voltage: 380±20V
- ♦ Wider wind speed operation range
- Higher efficiency

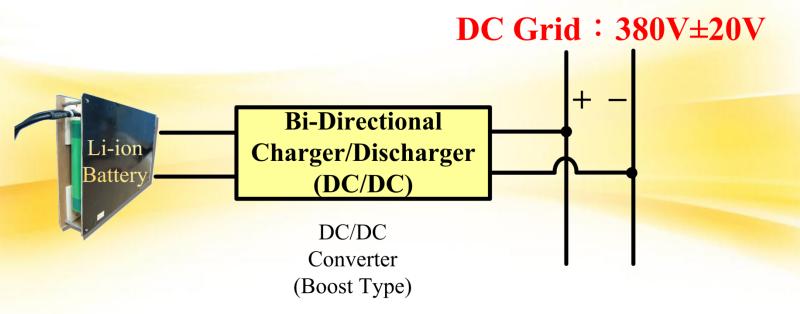
Fuel Cells +DC/DC Converter DC Grid



- Fuel Cell Voltage: 48V~96V
- DC-Grid Voltage: 380±20V
- ◆For base power supply

Learne Storage Elements

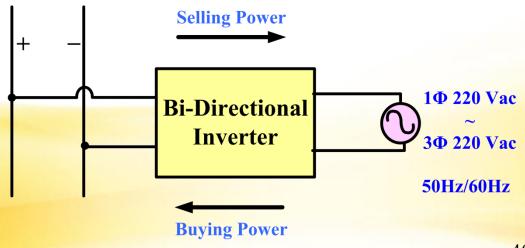
➤ Li- ion Battery



- Li-ion Battery Voltage: 96V
- Providing short-term power for loads
- Regulating DC-Grid voltage to 380 Vdc

Bi-directional Inverter

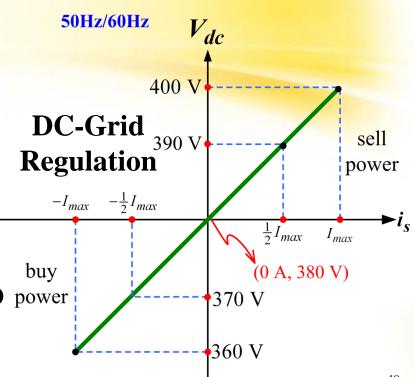
DC Grid: 380V±20V



◆Providing long-term power for loads

◆Selling power to AC grid or buying power from AC grid

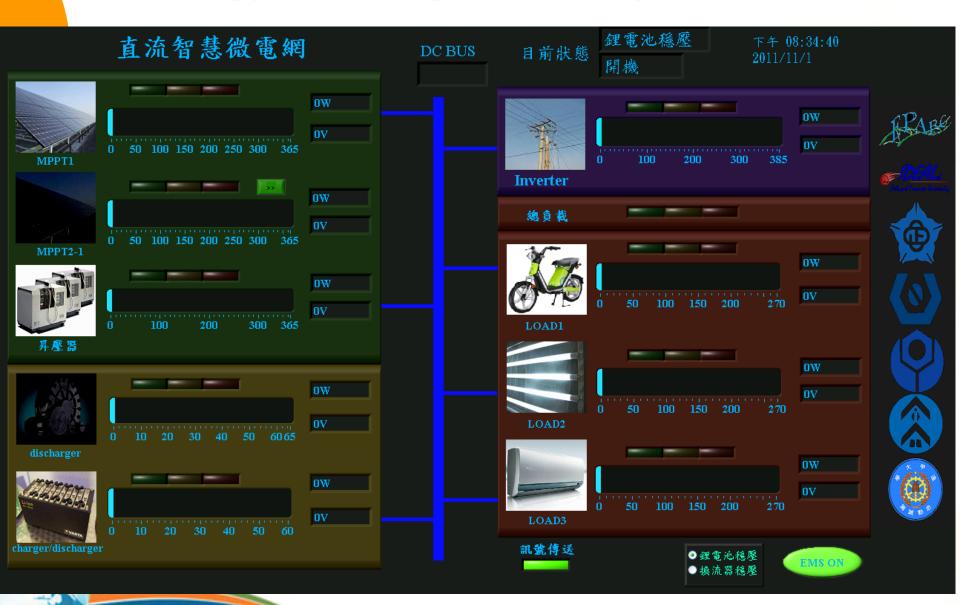
Regulating DC-Grid voltages to power 380±20V



DC Appliance and 3C Products

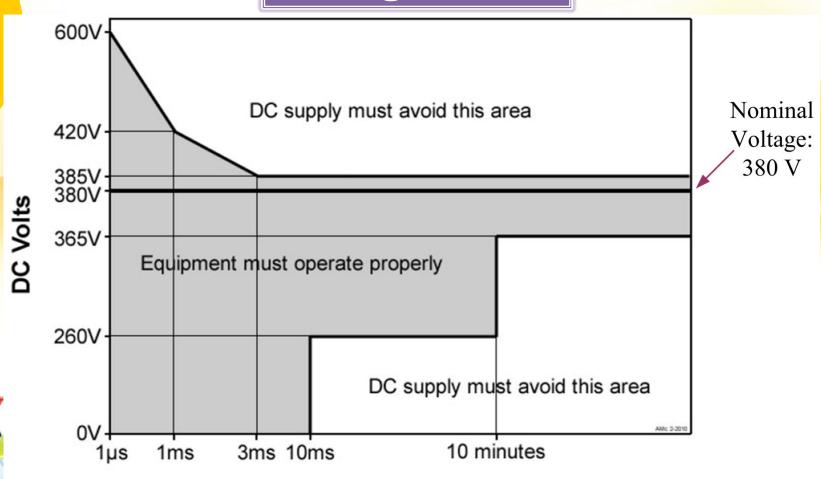


Energy Management System



DC-Voltage Specification

EMerge Allianc

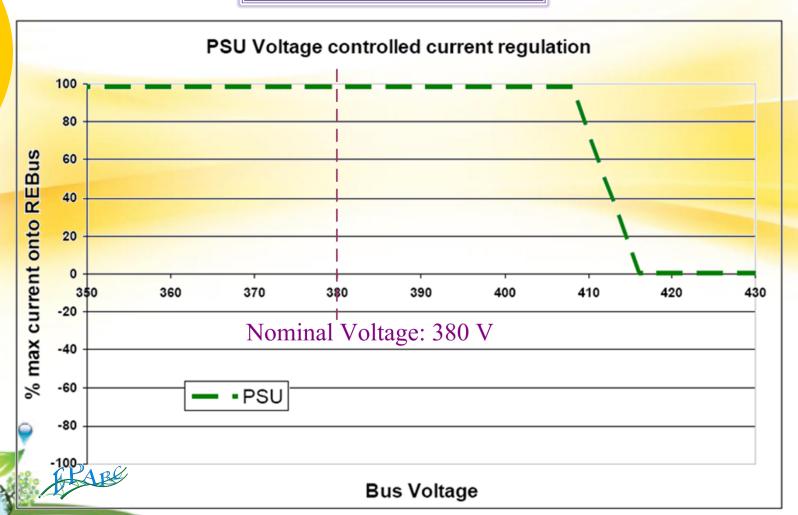


Duration

DC-Voltage Specification

REbus Alliance

(2011)



DC-Voltage Specification

400 V

380 V

360 V

340 V



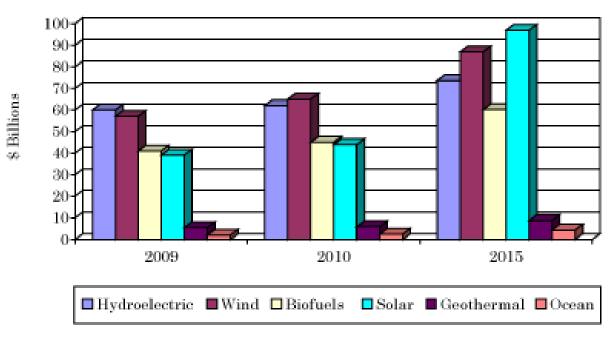


DC-Appliance Shut Down

For Emergency Use

Potential Market Size

SUMMARY FIGURE GLOBAL RENEWABLE ENERGY MARKET, 2009–2015 (\$ BILLIONS)



Source: BCC Research

(Solar Energy will reach \$ 97 billion by 2015, CAGR: 17 %)

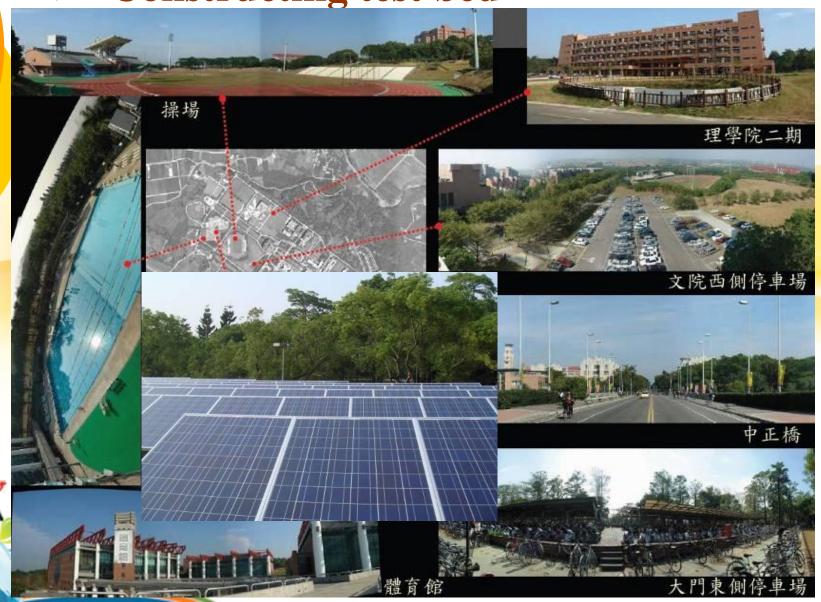
2014: PV installation $-15.4 \sim 37$ GW

(Sourec: Solarbuzz 2010 Market buzz)

(Today's PV - 0.012%; 2030 - 12%)

Opportunities

Constructing test bed



Developing & Manufacturing Key Components

- Power Converters/ Conditioners
- Energy Storage Systems
- Harmonizers (AC / DC Bi-directional Converter)
- Energy Management Systems
- Communication Modules
- DC Supplied Products



Providing Total Solution

◆ LVDC Side: 380 V

One-stop shopping service

- PV/Wind system design/installation
- DC electronic products
- Power conditioners/converters
- Plug, socket and breaker
- Wiring accessory





- ◆ MVDC Side: 10 ~ 50 kV
 - Generation/conversion
 - Transmission
 - Distribution
- ♦ HVDC Side: > 50 kV (Existing)
 - Generation/conversion
 - Transmission



Where to get started?

- Data Center
- Office building
- Telcom base station
- Newly constructed building



Challenges

- > Standard and Regulation require organization & government support
- DC products need industry support
- > Infrastructure all of us together



Concluding Remark

- Share of green energy grows very fast.
- We have to adapt to DC distribution with AC grid connection.
- A smarter grid requires new standards and regulations, DC electronic products, and infrastructures.



- No change no chance
 - Chance comes along with challenge



We've a lot of work to do, but we've a lot of chance to boom.